FEASIBILITY STUDY: ERADICATION OF KUDZU WITH HERBICIDES AND REVEGETATION WITH NATIVE TREE SPECIES IN TWO NATIONAL PARKS

RESEARCH/RESOURCES MANAGEMENT REPORT SER-59

U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
SOUTHEAST REGION

UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS NATIONAL PARK
TWIN CREEKS AREA
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Research/Resources Management Report SER-59

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April 1982

Submitted as an M.S. Thesis to the University
of Tennessee under National Park Service
Contract No. PX5000-0-0842

U.S. Department of the Interior
National Park Service
Southeast Regional Office
Natural Science and Research Division
75 Spring Street, S.W.
Atlanta, Georgia 30303

Rosen, Aaron. 1982. Feasibility Study. Eradication of Kudzu with Herbicides and Revegetation with Native Tree Species in Two National Parks. U.S. Department of the Interior, National Park Service, Research/Resources Management Report SER-59. 60 pp.

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CHAPTER I

INTRODUCTION

In the last 100 years there have been explosive introductions of previously restricted weedy vascular plants to all parts of the world. These exotic species have become a serious threat to the existence of native vegetation in many plant communities (Billings 1970).

Elton (1958) used the term "ecological explosions" to describe situations in which organisms are no longer controlled by forces that normally keep them in check. This term can be appropriately used to describe many exotic plant invasions. Thomas (1974) referred to these exotic invasions as "a type of biological pollution of an ecosystem," in which the minimum impact on an area would be either displacement of an indigenous plant or the occupancy of a vacant niche by an exotic plant.

The threat posed by exotic plants is considered to be one of the most critical problems facing parks in the National Park System today (National Park Service 1970). Thomas (1974) concluded that *Lonicera japonica* and *Hedera helix* (nomenclature follows Radford et al. (1968)) were destroying the forest on Theodore Roosevelt Island in the Potomac by suppressing natural regeneration. The National Park Service (1980) has reported that a total of 120 parks face resource management problems associated with the encroachment of exotic plants in natural vegetation communities.

Among the many exotic plant invaders in the southeastern United States, none is more highly visible and troublesome than kudzu, *Pueraria lobata* (Willd.) Ohwi. Kudzu, an introduced vine from Japan, was greatly esteemed during the first half of this century for its ability to control soil erosion, provide

feed for livestock, and restore soil fertility. With its prodigious growth rate and climbing habit, however, kudzu is difficult to control. Today it is considered a serious pest as it kills trees and shrubs and inhibits natural regeneration. Kudzu also is an economic problem, as it has invaded many acres of valuable timberland.

The overall goal of this research was to determine whether it is feasible to reclaim land infested with kudzu. The primary objectives were (1) to find a safe and effective method of eradicating kudzu from a given area, and (2) to determine an effective regime for quickly revegetating that same area with native tree species. In order to fulfill these objectives, two distinct studies were required. These are discussed in separate chapters, each with its own methods and results sections. This research was conducted at Chickamauga and Chattanooga National Military Park in Chattanooga, Tennessee, and at Cumberland Gap National Historical Park near Middlesboro, Kentucky.

CHAPTER II

DESCRIPTION AND HISTORY OF KUDZU

Description of Kudzu

The morphology of kudzu was described by Romm (1953). It is a deep-rooted, perennial, leguminous vine with stems that may reach a length of more than 70 feet in a single growing season. The stems are usually less than 1 cm in diameter. The leaves are alternate, trifoliate, and pubescent. The leaflets have short, thick stalks with lobed or entire margins. A tap root develops from the primary root of the seedling with many lateral roots developing early on the primary root. Adventitious roots develop from stolons when they come in contact with moist soil.

Flowering occurs in late August or early September (McKee and Stephens 1943). The flowers are pedicellate, borne in racemes near the end of the stem. The number of flowers in an inflorescence varies from a few to over 300. The peduncles and pedicels are pubescent. The calyx is tubular, dark red-purple, and densely covered with tan-colored hairs. There are five petals, 10 stamens of unequal length, and a unicarpellate pistil about 19 mm long (Romm 1953).

Each inflorescence bears from 10 - 30 yellow-green pods that have many long reddish-brown hairs. The pods are 5 - 8 cm long and about 1 cm wide, each containing 3 - 10 kidney-shaped seeds, about 3 mm long and 2 mm wide, covered by a hard, impermeable seed coat (Romm 1953).

A seed-collecting campaign was conducted in the fall of 1941 in the southeastern United States for seedling production in Soil Conservation Service nurseries. Tabor (1942) observed that the best seed production was obtained

from older vines in small to medium-sized trees in permanent pastures with deep topsoil. He reasoned that the above conditions provided a limited area for continued growth, a pruning of lower leaves by grazing, and good moisture storage capacity in the soil.

The fleshy roots of kudzu contain a high percentage of starch, the main carbohydrate storage product (Pierre and Bertram 1929). Root storage depends on vigorous top growth, which in turn depends on food storage in the roots. Pierre and Bertram (1929) studied the effects of frequency of cutting on root storage. They found that the fewer the number of cuttings during a growing season, the greater was the increase in the weight of the roots. As the number of cuttings increased, the percentage of starch and nitrogen in the roots decreased, while the percentage of sugars increased. This indicated that as more cuttings were made, starch was converted to sugar to produce new top growth.

Under favorable soil conditions, in an undisturbed stand of kudzu, the roots may penetrate to a depth of 3 feet or more (Bailey 1939). Willard (1926) found roots that extended to a depth of 6 feet.

Kudzu grows best in the humid Southeast, although it will do reasonably well in the Southwest when irrigated (McKee and Stephens 1943). Kudzu is not winter hardy. In Georgia growth begins about the first of April and continues until the first frost. North of Virginia and Kentucky the winters are severe enough to kill the vines back to the original crowns each year. Based on experiments conducted in several northern states, kudzu, due to its inability to withstand cold temperatures, was found to be of no value north of the Ohio River (Williams 1924).

Kudzu has been grown successfully on most of the soils of the Southeast with the exceptions of the lime soils of the Black Belt section of Alabama and Missippi, deep infertile sandy soils, and poorly drained heavy clay soils. Kudzu was found to grow well on soils with a pH range of 4.5 - 7.0 (Bailey 1939).

Historical Background

The Japanese used kudzu as a shade plant around their exhibits at the Philadelphia Exposition in 1876, and it later became popular for shade around buildings in the South. Bailey (1944) described one possible scenario which may have led to the discovery of other uses for kudzu. Old vines were cut from trellises around porches and thrown into gullies along with other rubbish. If enough soil washed down and covered the vines, they rooted and sprouted in the spring. Eventually the vines completely covered the gullies. Farmers also noticed that whenever livestock came into contact with the vine they ate it readily. However, kudzu was not immediately popular among the general public for two reasons. One was a lack of knowledge about how to get it started, and secondly there was a fear that once it was started it could not be stopped (Bailey 1944).

Kudzu was strongly promoted by the U.S. Department of Agriculture during the 1930's and 1940's (Sturkie and Grimes 1939, McKee and Stephens 1943). It was touted as a plant that would grow vigorously under unfavorable soil conditions, produce a dense ground cover to protect the surface of the soil, restore the fertility of eroded areas, protect highway banks, maintain itself without replanting, and provide forage for livestock.

Perhaps the most inviting aspect of kudzu was its ability to control erosion. Soil erosion had become widespread in the South due to poor

agricultural practices, such as continuous growing of row crops on steep slopes (Bailey 1939). Bailey (1939) advised farmers to grow kudzu on steep slopes in a rotation system with other crops, so that land otherwise too steep to cultivate could be cultivated. He also stated that kudzu could be used on land that had eroded so badly that other crops could not be grown.

In addition to erosion control on farm lands, Bailey (1939) recommended kudzu for protection of highway and railway banks and fills, diversion channels, and gullies. In an experiment reported by Bailey (1939), one side of a roadbank was planted in kudzu and one side was sodded in the spring of 1936. By the end of the 1937 growing season the kudzu bank was completely protected while the sod had not made sufficient growth to control erosion by the summer of 1938.

In a study conducted by the Soil Conservation Service Experiment Station at Watkinsville, Georgia from 1943 - 1946, cotton and kudzu were planted on slopes averaging 11 percent. The average annual loss of topsoil from the slopes in cotton was 26.23 tons per acre. The average loss for the slopes in kudzu was 0.20 tons per acre (Cope 1950).

Mauer (1949) reported that the live roots of one acre of kudzu weighed an average of 26,000 lb. He concluded that this accounted for kudzu's ability to rebuild soil as well as hold it in place.

Kudzu was planted at Copperhill, Tennessee in 1955 in an effort to revegetate the denuded landscape, control erosion, and regenerate soil and biota. It was somewhat successful in the initial stages, but growth was checked apparently due to immobilization of phosphorous and nitrogen in the litter and humus (Witkamp et al. 1966).

For hay production and grazing kudzu was found to have a feeding value as high or higher than alfalfa (Bailey 1939). It produced larger yields than most annuals grown for hay and had the advantage of not having to be planted every year. One disadvantage was the difficulty of harvesting, as the long vines would get caught in the mower. However, an accessory was available which could divide and free the vines (McKee and Stephens 1943). Kudzu harvested for hay in various places in Alabama produced over 2 tons per acre (Sturkie and Grimes 1939).

For grazing of beef and dairy cattle kudzu was able to support one cow per acre with good results. On experimental plots at Auburn, Alabama, one acre of kudzu produced an average of 128 lb of beef per season. Dairy cows reportedly produced more milk on kudzu than on grass with no difference in color or flavor of the milk (Sturkie and Grimes 1939). It was also demonstrated that hogs and chickens did well on kudzu.

Kudzu was also widely heralded as a builder of soil fertility. On experimental plots at Auburn, sorghum, corn, and oats were grown on land which had had three prior years of kudzu and compared with crops grown on land which had had no kudzu previously. All three crops grown on land with prior kudzu had significantly higher yields than the control. Increased yields were still apparent after 10 years. The authors concluded that kudzu had greatly improved the soil's fertility (Bailey and Mayton 1931).

Jordan et al. (1956) compared the effects of continuous corn with a kudzu-corn rotation on various soil properties. Kudzu was grown for four years followed by corn. After the four years of kudzu, the nitrogen, organic carbon, and exchangeable potassium were all higher than in the continuous corn plots. Corn yields showed a significant increase following the kudzu.

Kudzu was not considered a pest by the early writers. Bailey (1939) said that although vines could cover trees in nearby woodlands, the damage to the trees would be no greater than the effect of tree encroachment on cultivated land. Bailey went on to say that encroachment could easily be prevented by plowing along the border three or four times during the growing season.

Most authors felt that kudzu could easily be eradicated by fire, plowing, or overgrazing. Bailey (1939) maintained that kudzu could be eradicated in one season by plowing or in two to three seasons by close grazing. McKee and Stephens (1943) recognized that kudzu could be a nuisance when growing in unwanted places, but felt it could be killed easily enough. Sturkie and Grimes (1939) reported that kudzu had been confined at Auburn for 35 years without spreading into areas where it was unwanted. Brink (1942) quickly dismissed the possibility of kudzu becoming a pest and said "Southern farming needs kudzu and more kudzu, needs it quickly and in quantity."

Kudzu is now recognized as a serious noxious weed (Patterson 1976). It is a nuisance in timberland, rights-of-way, and along utility transmission lines (Hardcastle 1969). An estimated 2 million acres of forest land in the Southeast are infested with kudzu (Fears and Frederick 1977). Kudzu inhibits the establishment of tree seedlings and can cover trees 80 feet tall (Brender 1960).

All of the recent literature on kudzu deals with ways to get rid of it. Numerous research efforts have been made to find the most efficient and economical way to eradicate kudzu (Brender 1960, 1961, Brender and Moyer 1965, Dickens and Buchanan 1971, Fears and Frederick 1977, Chappell and Link 1977). Among the possible techniques are fire, grazing, herbicides, and mechanical treatment. The majority of the research has dealt with the use

of herbicides, such as 2,4-D, 2,4,5-T, picloram and dicamba. Before its use was outlawed, 2,4,5-T was only moderately successful. Davis and Funderburk (1964) found that 13 treatments over a five-year period were required to eradicate kudzu using a combination of 2,4-D and 2,4,5-T.

The most effective herbicide to date appears to be Tordon (picloram). It is a non-selective herbicide that kills all broadleaf plants, including trees, and remains active in the soil for approximately one year (Brender and Moyer 1965).

Robertson (1971) found grazing to be effective and economical. Kudzu was practically eliminated from a 500 acre tract in three seasons of grazing. Spot treatments of herbicide were necessary to kill the few remaining vines. On very steep slopes grazing may be impractical or impossible.

Fire has been mentioned as a good pre-treatment to facilitate herbicide application, but not as a treatment by itself (Brender 1961). Fire would reduce the litter layer but not kill all of the crowns. Since kudzu reproduces mainly vegetatively, new runners would grow quickly from the unharmed crowns.

The early promoters of kudzu did not foresee the problems that might be caused by the plant, nor did they anticipate that thousands of farms in the Southeast would be abandoned after World War II (Robertson 1971). Introduced plant species usually fail to compete with native species which are adapted to each other and their environment (Oosting 1956). However, sometimes species get established which are capable of causing extensive community changes (Penfound 1966). This was the case with kudzu. Once left untended it spread rapidly into nearby woodlands.

CHAPTER III

HERBICIDE TREATMENTS

Introduction

As discussed in Chapter I, one of the objectives of this research was to find a safe and effective method of eradicating kudzu from a given area. Experimental plots were established at Cumberland Gap National Historical Park and at Chickamauga and Chattanooga National Military Park. The effectiveness of several herbicide treatments was tested on these plots.

Materials

Two herbicides were chosen for testing: Roundup (glyphosate) and Velpar Gridball (hexazinone). These two herbicides were chosen in order to compare a foliar-uptake herbicide (Roundup) with a root-uptake herbicide (Velpar). Both were considered to be relatively safe and to have a reasonably good chance of success.

Roundup is a broad-spectrum, relatively non-selective herbicide reputed to be effective on deep-rooted perennial species and on annual and biennial species of grasses, sedges, and broad-leaved weeds. It is applied as a post-emergence spray to foliage, through which it is absorbed and translocated throughout the plant. A post-emergence application is one that is made following the emergence of the weeds from the soil or following the appearance of new leaves in the spring.

Results published by the Weed Science Society of America (1979) indicate that glyphosate has low phytotoxicity and very low leaching characteristics. Degradation by microorganisms is the major cause of glyphosate decomposition in soil. Glyphosate has no pre-emergent activity and thus crops can be

planted or seeded into treated areas immediately following application. Soil residues are usually 10% or less of the amount applied within a growing season (Weed Science Society of America 1979). Many species of fish and wildlife, such as bobwhite quail, mallard ducks, honeybees, rainbow trout, and bluegills have an extremely high tolerance to glyphosate. In terms of acute toxicity, the oral LD50 for rats is 4900 mg/kg (Weed Science Society of America 1979).

Roundup was applied to kudzu in a 2% solution using a backpack sprayer. It was applied on a spray-to-wet (dew-like appearance) basis. Each plot was sprayed with sufficient Roundup to insure good coverage. Each Roundup treatment actually consisted of two applications, the second coming approximately two weeks after the first, in order to treat any foliage missed in the first application.

Two different application strategies were used to determine whether time of application has any bearing on the herbicide's effectiveness on kudzu. It was hypothesized that Roundup would be more effective when the leaf area to crown ratio of kudzu was greatest, providing the maximum surface area from which herbicide could be absorbed, and that therefore a late summer application would be more effective than an early summer application. The early summer application was made in June and the late summer application was made in August.

The second herbicide tested was Velpar Gridball, which is manufactured in pellet form. It is a root-uptake herbicide and was chosen to compare a root-uptake herbicide with the foliar-uptake Roundup. Velpar Gridball is designed for forestry uses, mainly for control of unwanted hardwood species

in pine stands. It is safe for use in stands of loblolly, longleaf, shortleaf, slash, and Virginia pines.

Velpar can be applied before or during the period of active plant growth. The pellets are placed on the soil surface in a grid pattern. Rain dissolves the pellets and carries the herbicide down into the root zone from where it is absorbed and translocated throughout the plant. Three to four inches of rainfall are needed for activation.

Persistence of Velpar in the soil in field tests varied from one to six months. Microbial degradation contributes to decomposition in the soil. The general toxicity to wildlife and fish is considered to be low. The oral LD50 for rats is 1690 mg/kg (Weed Science Society of America 1979). The pellets were hand-placed approximately 4 ft apart in a grid pattern, which resulted in the use of 20 lb/acre. One treatment consisted of Velpar alone, applied in May, and a second treatment consisted of Velpar applied in May followed by a June application of Roundup. It was hypothesized that a Velpar-Roundup treatment would be more effective than either chemical used alone.

Methods

The following four herbicide treatments were tested:

1) Roundup - June application
2) Roundup - August application
3) Velpar
4) Velpar followed by June Roundup

All of the above herbicide treatments were administered in the spring and summer of 1980.

Each treatment was replicated three times at Cumberland Gap National Historical Park and twice at Chickamauga and Chattanooga National Military

Park. Plots were located in areas of dense kudzu and treatments were randomly assigned to plots with one restriction. Since Velpar is a root-uptake herbicide, it was not assigned to a plot if there was a possibility that feeder roots of nearby trees might be within the plot. On such plots either June Roundup or August Roundup was randomly assigned.

Three sets of treatment plots were located at Cumberland Gap. Each set consisted of four plots, one for each treatment. Two of the sets were located along U.S. Highway 25E at the base of the rise leading to the Gap. Slope angle ranged from 19-28 degrees on one set of plots and 15-19 degrees on the second set. Both sets were on northwest-facing slopes. The third set of plots was at the top of the Gap on level terrain.

The two sets of plots at Chickamauga-Chattanooga National Park were located on a northeast-facing slope at the foot of Lookout Mountain. Each set again consisted of four plots, one for each treatment. Slope angle ranged from 15-22 degrees one one set and from 22-25 degrees on the other.

Each treatment plot was 10 x 20 meters and situated with the longer side parallel to the slope. A 4 x 20 meter strip was marked off down the center of each plot. While the entire 10 x 20 meter plot was treated with herbicide, only the 4 x 20 meter strip was sampled for effectiveness ratings. This was done to provide buffer zones to prevent confounding of treatments. As an additional precaution, vines were cut between adjacent plots using a gasoline-powered weed cutting device. The perimeter of each treatment area was sprayed with Roundup to prevent encroachment of kudzu from outside the area.

Each 4 x 20 meter strip was subdivided into 80 1-meter square quadrats. Two quadrats were randomly chosen from each of five slope positions for a

total of 10 sample quadrats (Figure 1). The number of live crowns in each of the 10 quadrats was recorded. The total number of live crowns in the 10 quadrats was multiplied by eight to arrive at an estimate for the 4 x 20 meter strip. This was used as the pre-treatment estimate of the number of live crowns in each plot. All pre-treatment sampling was conducted in April, 1980.

The post-treatment estimate was simply a count of the total number of live crowns in the entire 4 x 20 meter strip. During the post-treatment crown count a distinction was made between vigorous crowns and surviving crowns. A crown was considered to be vigorous if it had normal healthy-looking foliage. If the foliage was chlorotic or deformed, the crown from which it came was considered to be surviving. All post-treatment crown counts were made in September, 1980.

A percent cover estimate of live kudzu remaining in each plot after treatment was also made in September, 1980 by visually estimating the percent kudzu cover in each of the 80 square meter quadrats and using the mean as an estimate of the percent live kudzu cover for the 4 x 20 meter strip. All plots were considered to have had 100% kudzu cover prior to treatment.

After all post-treatment crown counts and percent cover estimates were completed, the remaining kudzu on all plots was sprayed with Roundup in mid-September in order to remove as much additional kudzu as possible. This was done to better prepare the area for the revegetation part of the study the following spring.

Soil samples were collected from each set of plots prior to herbicide application in May, 1980. Each sample consisted of approximately 20 cores randomly collected at each set of plots at a depth of 0-6 inches. In September,

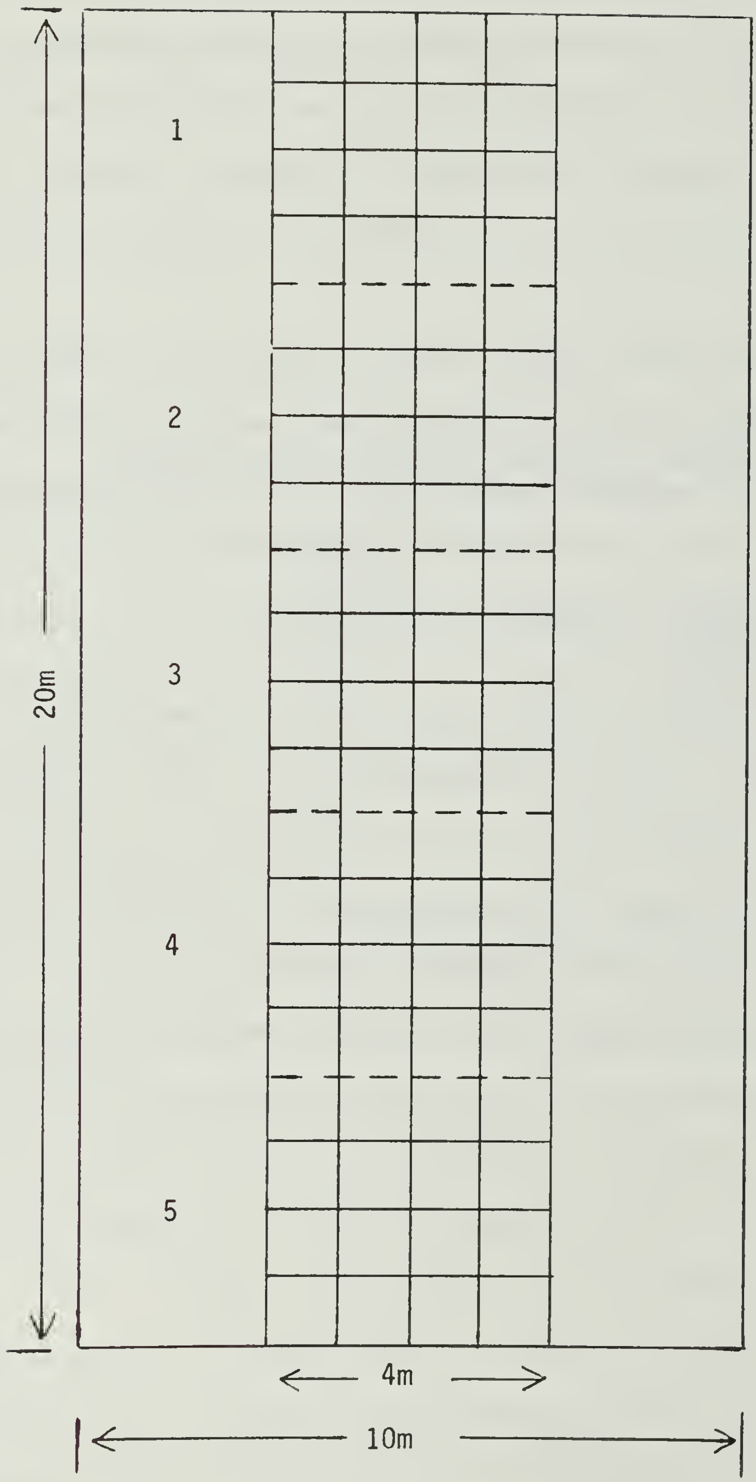


Figure 1. For each 10x20m plot 2 quadrats were randomly chosen from each of the 5 slope positions shown.

1980 samples were again collected. One sample was collected from each plot treated with Velpar and one sample from each plot treated with August Roundup. Samples were analyzed for hexazinone (Velpar) by the Tennessee State Pesticide Analytical Laboratories in Nashville. Samples were not analyzed for glyphosate due to the high cost of obtaining the necessary equipment.

Data were analyzed using Statistical Analysis System (SAS) packages (Helwig and Council 1979). Frequencies and means were calculated, and Duncan's multiple range test was used to test for significant differences among means.

Results and Discussion

The effectiveness of the herbicide treatments was measured in terms of percent kudzu cover and the number of live crowns remaining after treatment. The number of live crowns was expressed as a percentage of the original number of crowns prior to treatment. The number of live crowns was divided into vigorous and surviving as defined previously.

The number of remaining live crowns on Velpar-treated plots was not counted. The preponderance of kudzu cover on these plots made it exceedingly difficult to get an accurate estimate of numbers of crowns. It was clear that the Velpar treatment had not been effective and the number of remaining live crowns was probably close to the original number.

As can be seen from Table 1, in terms of percent kudzu cover remaining after treatment at Lookout Mountain, all four treatments differed significantly from each other. Seven percent kudzu cover remained on plots treated with August Roundup, while 93% kudzu cover remained on plots treated with Velpar. There were no significant differences among the three Roundup treatments

Table 1. Mean percent kudzu cover and mean number of live crowns remaining after treatment, September, 1980 at Lookout Mountain

Treatment	Percent kudzu cover	Crowns*		
		Vigorous	Surviving	Total
1) June Roundup	59 c**	12 a	23	35 b
2) August Roundup	7 a	3 a	13	16 a
3) Velpar	93 d	-	-	-
4) Velpar-Roundup	22 b	5 a	40	45 b

*Expressed as a percentage of the number of crowns prior to treatment.

**Means with the same letter are not significantly different at the .05 level of probability.

in terms of vigorous crowns. However, in terms of total crowns, August Roundup had significantly fewer remaining crowns than the other two treatments.

It should be noted that while the total number of crowns remaining was fairly high, most of these were not vigorous. A majority of the remaining live crowns had foliage that was sparse, deformed, or chlorotic. This was clear evidence of herbicide toxicity. Whether the surviving crowns would have eventually died or would have been able to withstand the toxic effects is impossible to answer since all plots were sprayed with Roundup in mid-September to prepare for the revegetation treatments.

At Cumberland Gap (Table 2), there were no differences among the three Roundup treatments in terms of kudzu cover. All three Roundup treatments were significantly more effective than Velpar alone, which had 80% remaining kudzu cover. In terms of crowns, the Velpar-Roundup treatment had significantly fewer total crowns (18%) than the other two Roundup treatments (51% each). The majority of remaining live crowns at Cumberland Gap were also not vigorous.

Results from Lookout Mountain appear to substantiate the hypothesis that a late summer application of Roundup is more effective than an early summer application, since the August Roundup treatment had less kudzu cover and fewer total crowns than the June Roundup treatment. However, based on results from Cumberland Gap, the hypothesis would have to be rejected, because there was no significant difference between August Roundup and June Roundup either in percent cover or total crowns remaining after treatment.

It is clear that Velpar alone was ineffective at both parks. Ninety-three percent kudzu cover remained at Lookout Mountain and 80% at

Table 2. Mean percent kudzu cover and mean number of live crowns remaining after treatment, September, 1980 at Cumberland Gap

Treatment	Percent kudzu cover	Crowns*		
		Vigorous	Surviving	Total
1) June Roundup	25 a**	6 a	45 b	51 b
2) August Roundup	9 a	1 a	50 b	51 b
3) Velpar	80 b	-	-	-
4) Velpar-Roundup	11 a	1 a	17 a	18 a

*Expressed as a percentage of the number of crowns prior to treatment.

**Means with the same letter are not significantly different at the .05 level of probability.

Cumberland Gap. The manufacturer, Dupont, claims that 3-4 inches of rainfall are necessary for activation of the herbicide and it would appear that there was sufficient rainfall at both parks for activation (Table 3). However, had the precipitation for the summer of 1980 been in amounts closer to the norm, Velpar may have been much more effective. It may be important to note that Cumberland Gap, which had 2 inches of rain more than Lookout Mountain, also had 13% less kudzu cover than Lookout Mountain on Velpar-treated plots. It should also be recognized that herbicides in general are less effective when the target plants are under moisture stress. Herbicides have maximum effectiveness when plants are healthy and actively growing so that the active ingredient is translocated completely throughout the plant. Thus the relatively dry summers at both parks could have contributed to Velpar's ineffectiveness. Since Roundup is also indirectly dependent on adequate precipitation for maximum effectiveness, it too could have been more effective under more favorable moisture conditions.

The results from the Velpar-Roundup treatment were inconclusive with respect to the hypothesis that the combination of Velpar and Roundup would be more effective than Velpar alone or June Roundup alone. At Lookout Mountain Velpar-Roundup was more effective in terms of cover, but there was no difference in terms of crowns. At Cumberland Gap there was no significant difference between Velpar-Roundup and June Roundup in terms of cover, but Velpar-Roundup was significantly more effective in terms of crowns. Since Velpar alone was so ineffective, the effects of the Velpar and Roundup together were probably due largely to Roundup, although there may have been some slight synergistic effect.

Table 3. Precipitation data from Lookout Mountain and Cumberland Gap

	Precipitation*			
	Lookout Mountain		Cumberland Gap	
Month	1980	Normal	1980	Normal
June	2.27	3.68	1.11	3.58
July	1.28	5.14	4.17	4.91
August	0.96	3.22	2.32	8.01
September	4.26	3.69	3.30	1.25
Total	8.77	15.73	10.90	17.75

*Inches of rainfall.

Source: National Weather Bureau, Chattanooga, TN. and Middlesboro, KY.

The effects of the additional application of Roundup in September, 1980 on percent kudzu cover and live crowns can be seen in Tables 4 and 5. Percent cover and number of live crowns were estimated the following summer in June. Each treatment shown is the original treatment plus the additional September application of Roundup. Roundup was applied twice in the original treatments, but only once in September to each plot. Thus treatments 1, 2, and 4 consist of three applications of Roundup, while treatment 3 consists of only one application of Roundup.

At Lookout Mountain (Table 4), treatments 2, 3, and 4 had 13%, 21%, and 8% kudzu cover remaining, respectively. These were not significantly different. There was no difference between treatment 3 and the other treatments in terms of live crowns. Since Velpar alone had almost no effect on cover and presumably crowns, Roundup alone must have been responsible for the reduction in cover and crowns in treatment 3. Thus the one September application of Roundup was practically as effective as the other treatments, which consisted of three applications of Roundup. The one exception was treatment 1, which consisted of two applications of Roundup in June and one in September. Treatment 1, with 3% remaining kudzu cover, was significantly more effective than treatment 3.

At Cumberland Gap (Table 5), there was no significant difference between treatment 3 (single application of Roundup) and the other three treatments, in terms of percent cover. In terms of total crowns, there was no significant difference among treatments 1, 3, and 4. This again indicates that one September application of Roundup was as effective as two earlier applications and one September application. One explanation for the effectiveness of the September applications of Roundup may be the fact that precipitation for

Table 4. Mean percent kudzu cover and number of live crowns at Lookout Mountain after all treatments had received one additional application of Roundup in September, 1980

Treatment	Percent kudzu cover	Crowns* Vigorous	Crowns* Surviving	Crowns* Total
1) June Roundup	3 a**	1 a	10	11 a
2) August Roundup	13 ab	23 a	10	33 a
3) Velpar	21 b	22 a	9	31 a
4) Velpar-Roundup	8 ab	14 a	16	30 a

*Expressed as a percentage of the number of crowns prior to treatment.
**Means with the same letter are not significantly different at the .05 level of probability.

Table 5. Mean percent kudzu cover and mean number of live crowns at Cumberland Gap after all treatments had received one additional application of Roundup in September, 1980

Treatment	Percent kudzu cover	Crowns* Vigorous	Crowns* Surviving	Crowns* Total
1) June Roundup	5 a**	3 a	2	5 ab
2) August Roundup	23 a	13 b	8	21 ab
3) Velpar	4 a	5 a	10	15 ab
4) Velpar-Roundup	0 a	1 a	1	2 a

*Expressed as a percentage of the number of crowns prior to treatment.
**Means with the same letter are not significantly different at the .05 level of probability.

the month of September increased sharply over the previous month, especially at Lookout Mountain. If kudzu had been under moisture stress and suddenly received an abundance of rainfall about the same time as the herbicide was applied, it is quite likely that the herbicide would have been very effective for reasons discussed earlier.

At both parks percent kudzu cover increased on August Roundup plots from September, 1980 to June, 1981, and at Lookout Mountain the number of live crowns also increased. In comparison, percent kudzu decreased on all other treatments dramatically both in terms of cover and crowns. It is apparent that the final application of Roundup in September had little effect on kudzu in the August treatment plots.

One explanation may be that the September application was too close to the August application to allow time for any live crowns to resprout. Since there were live crowns at the time of application in September, but very little foliage from which herbicide could be absorbed, the crowns were spared the effects of the herbicide. The other treatments, on the other hand, had greater percent kudzu cover at the time of herbicide application in September, and therefore the herbicide would have been much more effective.

At the end of June, 1981 all kudzu which had resprouted was spot-treated with Roundup. Percent kudzu cover and number of live crowns were estimated again in July.

Tables 6 and 7 show the remaining percent kudzu cover and number of live crowns after spot treatment. At Lookout Mountain percent kudzu cover was not greatly reduced by the spot treatment (Table 6). However, the number of remaining live crowns was reduced considerably. At Cumberland

Table 6. Mean percent kudzu cover and number of live crowns remaining at Lookout Mountain after spot treatment with Roundup in June, 1981

Treatment	Percent kudzu cover	Crowns*		
		Vigorous	Surviving	Total
1) June Roundup	14	1	3	4
2) August Roundup	11	1	4	5
3) Velpar	25	2	5	7
4) Velpar-Roundup	10	2	4	6

*Expressed as a percentage of the number of crowns prior to treatment.

Table 7. Mean percent kudzu cover and number of live crowns remaining at Cumberland Gap after spot treatment with Roundup in June, 1980

Treatment	Percent kudzu cover	Crowns* Vigorous	Crowns* Surviving	Crowns* Total
1) June Roundup	3	0	3	3
2) August Roundup	8	0	3	3
3) Velpar	2	0	1	1
4) Velpar-Roundup	1	0	1	1

*Expressed as a percentage of the number of crowns prior to treatment.

Gap (Table 7) percent kudzu cover and number of live crowns were both decreased by the spot treatment.

Soil Samples

All pre-treatment soil samples contained less than 100 parts per billion (ppb) hexazinone (Table 8). Of the six post-treatment samples that were analyzed for hexazinone at Cumberland Gap, five contained less than 100 ppb. One sample contained 216 ppb. Three of the four samples at Lookout Mountain contained less than 100 ppb and one contained 516 ppb. Thus within four months of application all but two plots had returned to or near pre-treatment levels of hexazinone.

Summary

All three treatments involving Roundup were more effective than Velpar alone. Although not totally conclusive, it did appear that late season applications of Roundup were more effective than early season applications, especially when results of the September application were taken into consideration. There was no clear difference between the June application of Roundup and the combination of Velpar with June Roundup. The spot treatment with Roundup helped to reduce the amouunt of kudzu that had resprouted the following spring.

Table 8. Results of soil analyses for residual hexazinone at Lookout Mountain and Cumberland Gap

Rep	Pre-Treatment	Plot	Post-Treatment
		Cumberland Gap	
1	<100 ppb	3	< 100
		4	<100
2	<100	1	< 100
		4	216
3	<100	3	< 100
		4	< 100
		Lookout Mountain	
1	<100	2	< 100
		4	<100
2	<100	1	< 100
		4	516

CHAPTER IV

REVEGETATION

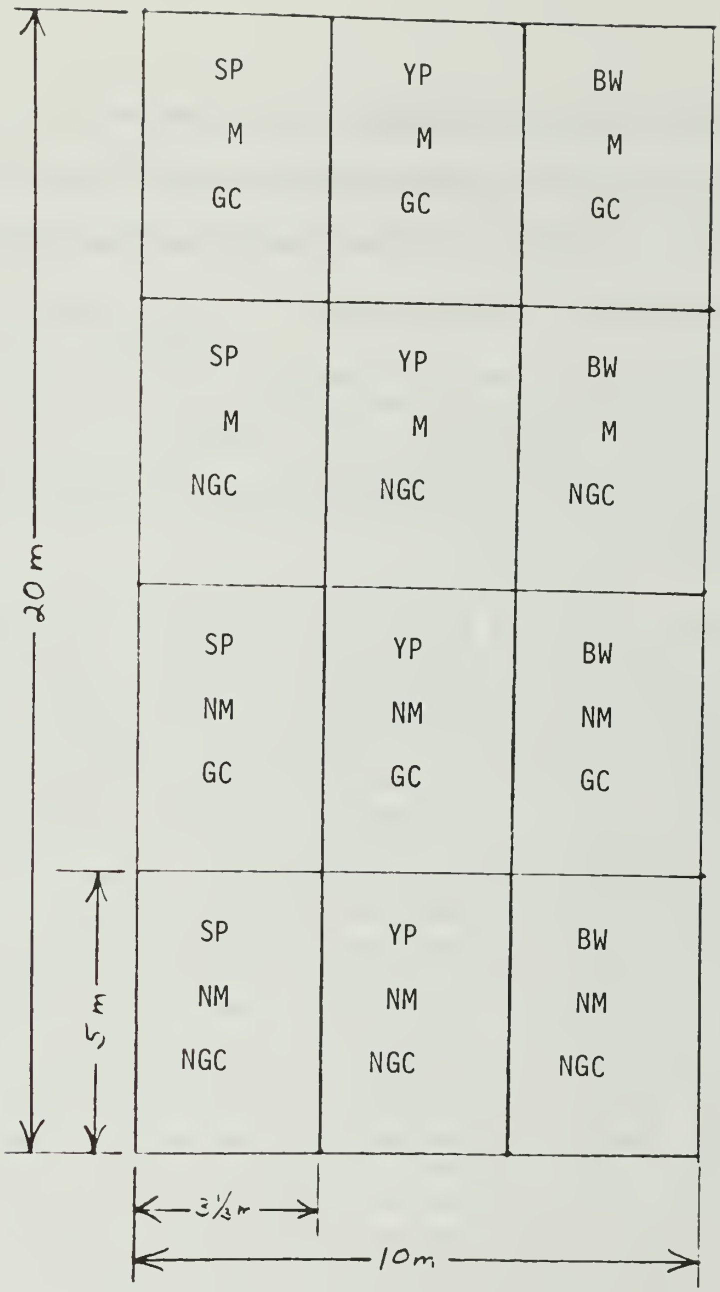
Introduction

The second part of the study was an attempt to determine an effective method for quickly revegetating the same areas that had previously been treated with herbicide. Seedlings of three different native tree species were planted on the sites to see whether it is feasible to revegetate an area before 100% eradication has been achieved. The seedlings were planted in combination with and without mulch, and with and without a seeded ground cover for a total of 12 different treatment combinations.

Methods and Materials

The 12 revegetation treatments were superimposed on each 10 x 20 meter herbicide plot in a randomized complete block design. Each 10 x 20 meter plot was divided into 12 subplots, each 5 x 3 1/3 meters (Figure 2). One treatment combination of tree species, mulch, and ground cover was randomly assigned to each of the 12 subplots. This was repeated on each 10 x 20 meter plot.

The tree species used were shortleaf pine (Pinus echinata), yellow-poplar (Liriodendron tulipifera), and black walnut (Juglans nigra). All three species are native to both parks and were considered compatible with the sites on which they were planted. Both pines and hardwoods were planted to test the hypothesis that pines are less susceptible than hardwoods to residual Velpar in the soil. Black walnut was chosen to test the hypothesis that it would have an allelopathic effect on kudzu. Fifteen seedlings were planted in each 5 x 3 1/3 meter subplot at a spacing of 0.8 meters in each direction.



Tree species	Mulch	Ground cover
SP-Shortleaf pine	M-mulch	GC-ground cover
YP-Yellor-poplar	NM-no mulch	NGC-no ground cover
BW-Black Walnut		

Figure 2. Each revegetation treatment consists of a tree species, mulch or no mulch, and ground cover or no ground cover. Each 10 x 20 m herbicide plot was divided into 12 5 x 3 1/3 m subplots and a single revegetation treatment was randomly assigned to each subplot.

Annual ryegrass (Lolium multiflorum) was chosen for the seeded ground cover, because it makes dense rapid growth in early spring and has been shown to offer severe competition to black locust seedlings (Vogel and Berg 1969). It was hypothesized that competition from the ryegrass would have an inhibitory effect on any kudzu that resprouted in the spring. It was also hypothesized that the ryegrass would have a negative effect on seedling survival as well. The ryegrass was seeded at the rate of 30 kg/ha (27 lb/acre) as recommended by Kipps (1970).

A straw mulch was applied to half of the subplots. It was hypothesized that the mulch would have an inhibitory effect on kudzu. Brender and Hodges (1957) showed that a 2 inch layer of sawdust was effective in controlling Lonicera japonica. It was also hypothesized that the mulch would have a positive effect on seedling survival since it reduces moisture loss from the soil. The mulch was applied at the rate of 5400 kg/ha, which was a depth of approximately 2 - 3 inches. Plass (1976) recommended that straw mulch be applied at rates of 2240 - 4480 kg/ha in reclaiming disturbed areas.

All planting, seeding, and mulching were carried out in March, 1981.

In June, 1981 seedling survival was assessed, live kudzu crowns counted, and percent kudzu cover estimated on each 10 x 20 meter plot. In addition, presence of naturally occurring herbs was recorded as well as a percent cover estimate for total herbaceous cover, excluding annual ryegrass and any grasses that appeared to be a result of the straw mulch.

At the end of June all kudzu which had resprouted was sprayed with Roundup using a 2% solution. It was applied using small spray bottles in an effort to keep the herbicide away from seedlings.

Results and Discussion

Despite the precautions taken, the spot treatments with Roundup did cause some mortality to seedlings. Therefore the analysis of the effects of mulch, ryegrass, and herbicide on seedling survival was based on survival data recorded in June, prior to treatment with Roundup.

Presence of the straw mulch had a slight positive effect on seedling survival at Cumberland Gap (Table 9). The survival rate for all species on mulched plots at Cumberland Gap was 94%, compared with 89% on unmulched plots. This difference was significant at the five percent level of probability.

If all species are considered together the data support the hypothesis that seedlings on mulched plots would have higher survival rates due to a reduction in moisture loss. The fact that the difference between mulched and unmulched plots was not greater was probably due to the generally favorable soil moisture conditions of spring and early summer.

At Lookout Mountain, on the other hand, there were no significant differences between mulched and unmulched plots either for individual species or for all species combined. This can probably be attributed to favorable soil conditions.

The presence of annual ryegrass had a slight negative effect on seedling survival at Cumberland Gap (Table 10). The survival rate for all species on seeded plots at Cumberland Gap was 90% and on unseeded plots 93%. Although this difference was very small, it was significant at the five percent level of probability. At Lookout Mountain, the survival rates on seeded and unseeded

Table 9. Effect of mulch on seedling survival at Lookout Mountain and Cumberland Gap

	Percent Survival				
	Cumberland Gap			Lookout Mountain	
Species	Mulch		No mulch	Mulch	No mulch
P. echinata	96		92	94	95
L. tulipifera	95		94	94	91
J. nigra	89		82	80	84
All species	94	*	89	89	90

*Significant at alpha = .05.

Table 10. Effect of annual ryegrass on seedling survival at Lookout Mountain and Cumberland Gap

	Percent Survival					
	Cumberland Gap			Lookout Mountain		
Species	Ryegrass		No ryegrass	Ryegrass		No ryegrass
P. echinata	92		96	92	*	97
L. tulipifera	95		95	90		94
J. nigra	84		88	82		82
All species	90	*	93	88		91

*Significant at alpha = .05.

plots were 88% and 91%, respectively. This difference was not significant. However, one species, shortleaf pine, did have a significant difference in survival rate between seeded and unseeded plots. Shortleaf pine had 92% survival rate on seeded plots and a 97% survival rate on unseeded plots. Thus, while the differences were slight, there was evidence that the seeded ryegrass offered enough competition to tree seedlings to negatively affect survival.

The combined effects of mulch and ryegrass on seedling survival are shown in Table 11. The poorest combination in terms of seedling survival at Cumberland Gap was ryegrass and no mulch. This is consistent with the hypotheses that ryegrass would hinder seedling survival and mulch would aid survival. At Lookout Mountain, there were no differences among the four combinations.

As mentioned previously the spot applications of Roundup did cause some mortality to seedlings. Table 12 shows the difference in overall survival for each species between June (prior to spot treatment) and July (following spot treatment). As can be seen from the table the greatest decreases in survival were at Lookout Mountain with yellow-poplar in particular showing the greatest mortality. The majority of the mortality was observed to be due to Roundup. The greater mortality at Lookout Mountain may have been due to the fact that the plots at Lookout Mountain were treated first. This "practice" may have led to greater precision with the sprayer at Cumberland Gap.

Survival data were also analyzed to see whether the presence of Velpar had any effect on seedling survival. Had there been sufficient amounts of residual Velpar in the soil, the survival rates of the hardwood seedlings should

Table 11. Combined effects of mulch and ryegrass on seedling survival at Lookout Mountain and Cumberland Gap

Mulch	Ryegrass	Percent survival Lookout Mountain	Percent survival Cumberland Gap
+*	-**	90 a***	95 a
+	+	88 a	93 a
-	-	93 a	91 ab
-	+	88 a	87 b

* + indicates presence of mulch or ryegrass.
** - indicates absence of mulch or ryegrass.
***Means with the same letter are not significantly different at the .05 level of probability.

Table 12. Seedling survival rates at Lookout Mountain and Cumberland Gap before (June) spot treatment with Roundup and after (July) spot treatment with Roundup.

	Lookout Mountain		Cumberland Gap	
Species	June	July	June	July
P. echinata	95	87	95	92
L. tulipifera	92	69	94	90
J. nigra	82	69	86	76
All species	90	75	92	86

have been adversely effected. Therefore survival data on plots treated with Velpar were compared with data on plots which did not receive any Velpar (Table 13). At Cumberland Gap the survival rate for yellow-poplar was significantly lower on Velpar-treated plots than on plots without Velpar. However, when the results of the soil tests for residual hexazinone were compared with survival data from the same plots, there was no apparent relationship between residual hexazinone and survival rate. As can be seen in Table 14, the mean survival rate on Velpar-treated plots for yellow-poplar was 91%. The survival rate on the plot containing 216 ppb hexazinone was also 91%. For black walnut the mean survival rate on Velpar-treated plots was 83%, while the survival rate on the 216 ppb plot was 86%. This indicates that the presence of Velpar had no effect on seedling survival at Cumberland Gap.

At Lookout Mountain no tree species appeared to be affected by the presence of Velpar. The mean survival rate for shortleaf pine on Velpar-treated plots was 91% (Table 15). The mean survival rate on the plot containing the most residual Velpar, 516 ppb, was 88%. While this is lower than the mean, it is not low enough to conclude that residual Velpar had a negative effect on survival. One would expect the survival rate to be much lower if Velpar were responsible for the difference.

The effects of species, mulch, and ryegrass on kudzu cover are shown in Table 16. The percent kudzu cover was estimated in June, prior to spot treatment with Roundup. Species had no effect on the amount of kudzu that resprouted at either park. Thus black walnut apparently had no immediate allelopathic effect on kudzu. A long-term study would be required to determine if black walnut would ultimately have an allelopathic effect on kudzu.

Table 13. Effect of Velpar on seedling survival at Lookout Mountain and Cumberland Gap

	Percent survival					
	Cumberland Gap			Lookout Mountain		
Species	Velpar		No Velpar	Velpar		No Velpar
P. echinata	94		94	91	*	98
L. tulipifera	91	*	98	91		93
J. nigra	83		88	83		82
All species	90		93	88		91

*Significant at alpha = .05.

Table 14. Residual hexazinone and percent seedling survival for each Velpar-treated plot at Cumberland Gap

Rep	Plot	Residual hexazinone	Percent survival		
			P. echinata	L. tulipifera	J. nigra
1	3	<100 ppb	98	88	82
1	4	<100	97	95	77
2	1	<100	98	90	78
2	4	216	95	91	86
3	3	<100	97	92	93
3	4	<100	82	95	85
Mean		-	94	91	83

Table 15. Residual hexazinone and percent seedling survival for each Velpar-treated plot at Lookout Mountain

Rep	Plot	Residual hexazinone	P. echinata	L. tulipifera	J. nigra
1	2	<100 ppb	92	87	79
1	4	<100	91	96	80
2	1	<100	93	85	83
2	4	516	88	93	88
Mean		-	91	91	83

Table 16. Effect of species, mulch, and ryegrass on percent kudzu cover at Lookout Mountain and Cumberland Gap

Treatment	Percent kudzu cover	
	Lookout Mountain	Cumberland Gap
P. echinata	13	9
L. tulipifera	12	6
J. nigra	16	9
Mulch	13	6
No mulch	15	10*
Ryegrass	12	9
No ryegrass	15	7

*Significant at alpha = .05.

At Lookout Mountain, there was no difference in percent kudzu cover between mulched and unmulched plots. However, at Cumberland Gap mulched plots had 6% kudzu cover while unmulched plots had 10% cover. This difference was significant at the five percent level of probability. Since kudzu is shade intolerant, the shade provided by the straw mulch may have limited incoming light to a sufficient degree to retard early growth.

There was no difference at either park in percent kudzu cover between seeded and unseeded plots. It was hypothesized that annual ryegrass would offer enough competition to reduce the percent kudzu cover on plots sown with ryegrass. This did not prove to be the case.

Table 17 shows the effects of species, mulch, and ryegrass on natural regeneration. Species had no effect at either park on the percent cover of naturally occurring herbs. Black walnut did not interfere with natural regeneration.

The presence of mulch had no effect on percent herb cover at Lookout Mountain. There was, however, an effect at Cumberland Gap. Mulched plots at Cumberland Gap had a 24% herb cover, while unmulched plots had a 33% herb cover. This was probably due not so much to the mulch itself, but to the fact that the straw contained a large amount of seed of miscellaneous grasses. Much of this seed germinated and grew in dense stands. These grasses undoubtedly competed with other potential herbs for space, water, light, and nutrients.

The presence of ryegrass had a significant impact on natural regeneration at both parks. At Lookout Mountain seeded plots had 40% natural herb cover, while unseeded plots had 57% natural herb cover. At Cumberland Gap the difference was even more pronounced. Seeded plots had an 8% natural herb

Table 17. Effect of species, mulch, and ryegrass on percent natural herb cover at Lookout Mountain and Cumberland Gap

Treatment	Percent herb cover: Lookout Mountain	Percent herb cover: Cumberland Gap
P. echinata	42	27
L. tulipifera	54	31
J. nigra	50	29
Mulch	46	24 *
No mulch	52	33
Ryegrass	40 *	8 *
No ryegrass	57	49

*Significant at alpha = .05.

cover, while unseeded plots had a 49% natural herb cover. Ryegrass germinated very early in the spring and established dense stands, which reduced germination and growth of other species.

The data were also analyzed to determine the combined effect of mulch and ryegrass on kudzu cover and herb cover. Table 18 shows that the combination of mulch and ryegrass made no difference in terms of percent kudzu cover at either park.

The combinations of mulch and ryegrass did, however, have an effect on herb cover. As can be seen from Table 19, the highest percent herb cover was on plots without mulch and without ryegrass. At Lookout Mountain there was no difference between mulched and unmulched on plots that had no ryegrass. At Cumberland Gap however, plots without ryegrass had a higher percent natural herb cover if they also had no mulch. This is because, as explained previously, the straw used at Cumberland Gap had a high percentage of seed which germinated and competed with natural herbs. The worst combination for herbs was mulch and ryegrass at both parks, although the differences were more pronounced at Cumberland Gap. As discussed previously, the annual ryegrass apparently outcompeted other herbs.

Table 20 lists the herb taxa recorded at Cumberland Gap on the experimental plots in June, 1981. Of the 18 taxa which were recorded, nine were classified as naturalized, according to the Survey of Exotic and Noxious Weeds of Tennessee (Herbarium 1979). At Lookout Mountain (Table 21), two of the eight recorded taxa were naturalized exotics. Thus, it appears that the exotic vine, kudzu, is being replaced by many annual and perennial exotic herbs. While native species would be preferred, weedy exotic herbs are preferable to kudzu for obvious reasons. The early successional weedy herbs

Table 18. Combined effects of mulch and ryegrass on percent kudzu cover at Lookout Mountain and Cumberland Gap

		Percent kudzu cover	
Mulch	Ryegrass	Lookout Mountain	Cumberland Gap
+*	+	13 a***	7 a
+	-**	13 a	4 a
-	+	12 a	11 a
-	-	17 a	9 a

* + indicates presence of mulch or ryegrass.
** - indicates absence of mulch or ryegrass.
*** Means with the same letter are not significantly different at the .05 level of probability.

Table 19. Combined effects of mulch and ryegrass on percent natural herb cover at Lookout Mountain and Cumberland Gap

		Percent herb cover	
Mulch	Ryegrass	Lookout Mountain	Cumberland Gap
-	-	58 a***	55 a
+*	-**	56 a	43 b
-	+	46 ab	12 c
+	+	35 b	5 c

* + indicates presence of mulch or ryegrass.
** - indicates absence of mulch or ryegrass.
*** Means with the same letter are not significantly different at the .05 level of probability.

Table 20. Presence list of herbs found on experimental plots at Cumberland Gap

Taxa	Status
Allium cernuum	native
Chenopodium album	naturalized
Chrysanthemum leucanthemum	naturalized
Cirsium vulgare	naturalized
Commelina communis	naturalized
Erigeron annuus	native
Galium aparine	native
Geranium carolinianum	native
Melilotus alba	naturalized
Melilotus officinalis	naturalized
Microstegium vimineum	naturalized
Oxalis stricta	native
Phytolacca americana	native
Rudbeckia hirta	native
Sonchus asper	naturalized
Specularia perfoliata	native
Trifolium pratense	naturalized
Verbesina occidentalis	native

Table 21. Presence list of herbs found on experimental plots at Lookout Mountain

Taxa	Status
Commelina communis	naturalized
Erigeron annuus	native
Galium aparine	native
Geranium carolinianum	native
Microstegium vimineum	naturalized
Oxalis stricta	native
Phytolacca americana	native
Specularia perfoliata	native

are transients, while kudzu is more permanent and threatened other vegetation.

Summary

The presence of the straw mulch had a positive effect on seedling survival at Cumberland Gap, but made no difference at Lookout Mountain. Ryegrass had a slight negative effect on seedling survival, although at Lookout Mountain the only species adversely affected was shortleaf pine. The presence of ryegrass and the absence of mulch was the worst combination for seedling survival at Cumberland Gap. At Lookout Mountain all combinations were the same statistically.

The presence of residual Velpar in the soil appeared to have no effect on seedling survival for any of the three species.

Of the three factors, species, mulch, and ryegrass, mulch was the only one that had any effect on kudzu cover. Mulch had a slight negative effect on resprouting kudzu, but only at Cumberland Gap.

Mulch had a small negative impact on natural herb cover at Cumberland Gap, while ryegrass had a negative impact on natural herb cover at both parks. In combination, mulch and ryegrass yielded the least amount of natural herb cover at both parks.

CHAPTER V

CONCLUSIONS

Although kudzu is a serious pest in many parts of the southeastern United States, it has certain characteristics which make it less noxious. Kudzu produces very small amounts of viable seed, but displays very rapid growth. This probably explains why kudzu is found in dense, but localized areas. This lack of seed production makes kudzu unlikely to be spread by wind, birds, and small animals. Another important characteristic of kudzu is its intolerance of shade. Even if kudzu were more prolific, it would probably not grow in those parts of the forest that have a closed canopy.

The above characteristics which tend to limit the spread of kudzu also make it easier to control. In this study the herbicide Roundup proved to be effective in controlling kudzu, while Velpar was totally ineffective. The August Roundup treatment was somewhat more effective than the June Roundup treatment, although the results were not totally conclusive. The results from the additional application of Roundup in September reinforced the hypothesis that a late season application would be more effective than an early season application.

Based on the results of this study it appears that 80 - 100% control can be achieved in a single growing season if repeat applications are used and they are timed far enough apart to allow foliage to resprout.

Whether active revegetation is undertaken by resource managers or whether natural regeneration is allowed to occur depends on the manager's purpose, philosophy, and monetary resources. In the humid temperate zone early successional species can colonize an area very quickly, even on moderately steep slopes. Thus natural regeneration is a viable alternative to

planting or seeding.

Based on the limited effect the straw mulch had on suppressing kudzu and also its limited effect on enhancing seedling survival, the use of a straw mulch would be questionable.

Since annual ryegrass had a negative effect on seedling survival, ryegrass and seedlings should not be used simultaneously. If a ground cover is desired for use in conjunction with tree seedlings, other ground covers which are less competitive might be considered. If a ground cover only is to be used, ryegrass has the advantage of making rapid early growth, but it is also a disadvantage for the same reason, since it outcompetes other herbs. If natural herb cover is desired, annual ryegrass should not be used.

In terms of tree species, all three that were used in this study had good early survival, ranging from 82 - 95% at Lookout Mountain and 86 - 94% at Cumberland Gap. Black walnut had the poorest survival of the three at both parks. This was due in large part to insect foraging.

In general, the outlook for controlling kudzu is very promising with Roundup. Of course, in many areas where kudzu grows, the value of the land would not be high enough to justify kudzu control. However, if the land is considered important for economic, historic, or ecological reasons, the possibility of reclaiming the land does exist.

Further research is indicated to determine just how long it takes to achieve 100% eradication with Roundup and whether it would be more efficient to allow a longer time period between herbicide application and revegetation. Longer-term research would also yield information on seedling survival over time, as well as data on the allelopathic effects, if any, of black walnut on kudzu.

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APPENDIX

Tables A and B show the costs of the various treatments used in this study. The number of seedlings per acre is based on the spacing used in this study, which was approximately 31.5 inches. The cost of one man-hour of labor was priced at $5.00 per hour.

Table A. Cost of herbicide treatments.

Herbicide	Roundup	Velpar
Unit price	$85/gal	$4.15/lb
Rate of application	1.5 gal/acre	20 lb/acre
Cost of herbicide/tmt.	$128/acre	$83/acre
Man-hours	20 mh/acre	10 mh/acre
Cost of labor	$100/acre	$50/acre
Total cost/tmt.	$228/acre	$133/acre

Table B. Costs of revegetation treatments.

Treatment	Mulch	Ryegrass	*P. echinata*	*L. tulipifera*	*J. nigra*
Unit price	$3.00/bale	$.30/lb.	$30/1000	$35/1000	$75/1000
Application rate	4800 lb/acre	27 lb/acre	6300/acre	6300/acre	6300/acre
Cost	$360/acre	$8/acre	$190/acre	$220/acre	$475/acre
Man-hours	10mh/acre	3mh/acre	210mh/acre	210mh/acre	210mh/acre
Cost of labor	$50/acre	$15/acre	$1050/acre	$1050/acre	$1050/acre
Total cost	$410/acre	$23/acre	$1240/acre	$1270/acre	$1525/acre

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.